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ODOUR IMPACTS - AN OVERVIEW

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ABSTRACT

This technical bulletin is intended as an overview to the issue of odour impacts. Information is provided on the nature of odour impacts; efforts to quantify and assess odour; common sources of odour impacts; and a review of some of the odour abatement technologies and techniques.

Many odour problems are unique to the location and processes causing the odour impacts. Although this bulletin provides an overview of the fundamentals of odour impacts, site specific reviews and an in-depth analysis of the appropriate industrial and air pollution control processes may be necessary. For further information or assistance, please contact the Environmental Engineering Services Section (Manager - Ed Turner, 416 323-5156).

1. BACKGROUND INFORMATION - INTRODUCTION TO ODOUR

Odour is a significant environmental concern for people around the world. For example, it is reported that most complaints, for a control agency in Australia, relate to undesirable odours. The results of this survey indicated that up to 91% of respondents perceived air pollution as odour, and 62% were annoyed by odours. Similarly, in Ontario, addressing public complaints represents a large proportion of the Ministry's abatement efforts and a significant number of these complaints relate to odour impacts.

Odour is a characteristic of chemical compounds that will depend upon the type of compound, the tone (ie., perceived pleasant versus unpleasant) and its concentration. However, odour is obviously subjective and relates to both the odour characteristic of the chemical and the sensitivity of exposed individuals. Chemicals that transfer readily from solid or liquid to air are termed volatile. Volatile Organic Compounds (VOCs) is a term that is intended to describe a variety of organic compounds that may be readily measured in the air phase. Many types of VOCs are odorous at relatively low concentrations. Sulphur is a chemical element that is found in a large number of materials. Many sulphur compounds (ie., Total Reduced Sulphur - TRS compounds such as hydrogen sulphide) are also odorous at relatively low concentrations. Ammonia and derivatives of ammonia (ie., amines) are also very odorous.

1.1 Common Sources of Odour

Almost any industrial, commercial or residential activity can be odorous depending upon the sensitivity of the individuals that are impacted. However, the following provides a summary of operations that commonly result in odour impacts:

iron & steel production; pulp & paper plants; oil refineries; chemical process plants; asphalt plants; rendering (food processing) facilities; foundries; landfills; compost facilities; paint and printing operations; wood dryers; wood combustion; and sewage treatment plants.

Many of these facilities emit a complex mixture of volatile organic compounds and/or sulphur compounds by themselves, in mixture or through chemical reactions with other pollutants can be odorous. However, some specific facilities minimize odour impacts through a combination of land-use planning; abatement technology/techniques and effective neighbour relations.

1.2 Characterizing Odour - The Odour Panel

Since the intensity of an odour impact is dependent upon the sensitivity of specific individuals, the odour characteristic of a chemical compound can only be described through a test on a range of individuals. A panel of typically nine or ten individuals is used to detect the odour of a compound at different concentrations in air. The results can be plotted on a curve of percent panel detection or response versus a logarithmic scale of concentration. The concentration at which 50% of the panel detects the odour is termed the odour threshold concentration for that compound. Figure 1, below, provides an example of an odour threshold curve (detection and complaint) for a specific compound.

However, day-to-day exposure to odour is typically caused by a mixture of compounds where the intensity and tone of the odour is difficult to consistently describe and predict.

The concept of an "Odour Unit" was developed to describe the odorous characteristic of a mixture of compounds. An odour unit is defined as the number of volumes or dilutions (**from a base value of 1.0 volume**) of clean odourless air that are required to make a mixture odourless to 50% of an odour panel. An odour unit is dimensionless (cubic metres of required dilution air per cubic metre of odorous mixture).

For example, a mixture that has an odour characteristic or intensity of 1000 odour units means that 1000 dilutions were required to make the mixture odourless to 50% of an odour panel. Alternatively, a mixture that has an odour characteristic of 1.0 odour unit is a mixture that is at its odour threshold (50% of an odour panel could not detect an odour). It is important to recognize that a compound or mixture at its odour threshold is anticipated to be detectable to 50 percent of an odour panel or 50% of the population so complaints could still be generated.

The Ministry has developed a draft protocol for source sampling for odours entitled, "Ministry of the Environment Province of Ontario; Air Resources Branch - Emission Technology & Regulation Development Section - Source Measurement Unit - Source Sampling for Odours (Version #2), February 1989". In addition, The American Society for Testing and Materials (ASTM) has published the a protocol,

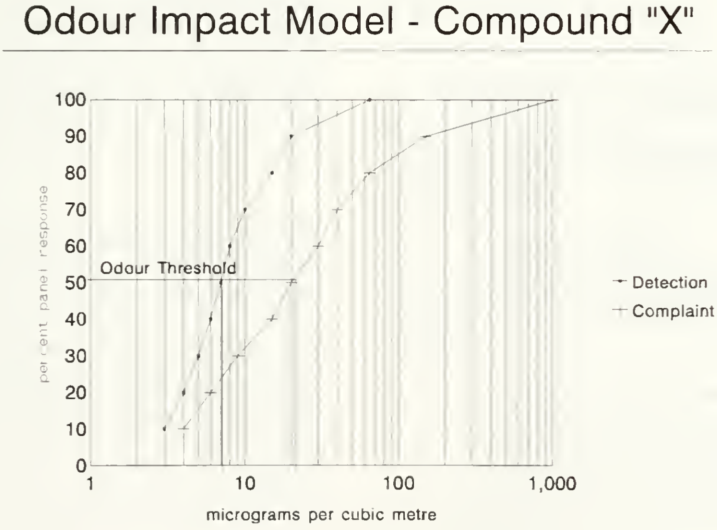

Figure 1

designated as ASTM E 679-79 entitled, "Standard Practice for Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series Method of Limits"

1.3 Dispersion Modelling Issues

The odour impact of a specific mixture will be a function of the odour intensity (ie., number of odour units); the volume of odorous gas; and the amount of dispersion of the gas between the source of emission and the individuals impacted by the emission.

The dispersion modelling calculations specified in Ontario Regulation 346 - General Air Pollution use a mass emission rate (grams per second) in conjunction with site geometry and typical or worst-case atmospheric conditions to estimate a half-hour average "point of impingement" impact of the emission in micrograms per cubic metre. Similarly, this dispersion modelling can be used to estimate the half-hour average impact of an odorous emission.

An odour emission rate can be calculated by multiplying the number of odour units (cubic metres of required dilution per cubic metre of gas) by the gas volumetric flow rate (cubic metres of gas per second) to give an odour emission rate (odour units per second). Application of the appropriate dispersion modelling calculations will result in an estimate of the point of impingement impact of the odour emission. Alternatively, application of dispersion modelling to the site-specific geometry using a nominal emission rate (e.g., 1 gram per second) will provide an estimate of the available atmospheric dilution. If the available atmospheric dilution is greater than the odour intensity of the emission (number of odour units) then the off-site impacts will be estimated to be less than the odour threshold, otherwise, the odour threshold is estimated to be exceeded.

One other relevant issue for dispersion modelling and odour impacts is the averaging period. Although a half-hour time period for averaging may be appropriate for mass concentrations of specific pollutants in Regulation 346, the response time of the human nose is significantly shorter and a half hour averaging period will significantly under-estimate potential odour impacts (ie., the peak impacts can be significantly greater than the average). Therefore an averaging period of a few seconds may be more accurate in predicting odour impacts at a point of impingement. The results of dispersion modelling for any averaging period (e.g., half-hour) can be converted to periods as short as 3 minutes using the following formula and table:

$$X_s = X_l(t_l/t_s)^p$$

where,
X_s = concentration for the shorter averaging time
X_l = concentration for the longer averaging time;
t_l = longer averaging time
t_s = shorter averaging time
p = exponent, as follows:

Atmospheric Stability	Exponent p
A - convective	0.5
B	0.5
C - neutral	0.33
D	0.2
E	0.167
F - very stable	0.267

An odour concentration at 3 minutes can then be converted to a peak odour impact condition using a factor of 10 for very unstable or convective conditions (stability A) and a factor of 5 for stabilities B-F. The conversion factors from half-hour average to peak can then be summarized as follows:

Atmospheric Stability	Half-Hour to Peak Conversion Factor
A	32
B	16
C	11
D	8
E	7
F	7

2. SOURCES OF ODOUR

The information in the following sections provides a summary of a few processes that are common sources of odour impacts.

2.1 Iron & Steel Production

There are a number of processes within an iron and steel production facility that are sources of odorous reduced-sulphur compounds such as hydrogen sulphide, including:

- quenching of slag (with limited quantities of water in large open pits) from the iron-making process (blast furnaces) is the primary source of odorous reduced-sulphur emissions from an iron and steel production facility. Sulphur in the slag comes from the coal used in the coke-making process that is subsequently used in the blast furnaces;

- quenching of coke from the coke ovens;

- coke ovens and by-product facilities (to recover combustible coke-oven gas and other by-products) are also minor sources of odorous reduced-sulphur compounds.

Future advancements in iron-making include the use of direct coal injection (to avoid the need for coke-making facilities) into the blast furnace. However, direct-coal injection may result in an increase in emissions of odorous reduced-sulphur compounds because coal typically has a sulphur content higher than coke.

2.2 Pulp and Paper Production

Odorous reduced-sulphur compounds such as hydrogen sulphide, methyl mercaptan, dimethyl sulphide and dimethyl disulphide are emitted from a kraft pulping process. The reduced-sulphur compounds originate from the "cooking liquor", used in the kraft pulping process, that contains a mixture of caustic soda and sodium sulphide. Reduced-sulphur emissions are common from the following processes in a kraft pulp and paper mill:

- digester (that combines wood with the cooking liquor);
- brownstock washing process (that separates the spent liquor from the pulp);
- evaporators (that concentrate the spent liquor);
- recovery boilers (that burn off the combustibles in the spent liquor leaving a "smelt" that is re-used to produce more cooking liquor);
- smelt dissolving tank where the smelt from the recovery boiler is combined with water;
- lime kiln (that is used to produce lime for addition with water and the smelt to produce the cooking liquor).

2.3 Oil Refineries

Oil refineries take crude oil from an oil production well and produce a number of fuels, lubricants, coatings and raw materials for the petro-chemical industry using a variety of separation and conversion processes (i.e., catalytic cracking and coking operations).

Crude oil and the products that are produced in an oil refinery are a mixture of compounds that are volatile at standard temperature and pressure. Some volatile organic compounds are odorous and are emitted from the oil refining process. In addition, since oil also contains sulphur, odorous reduced-sulphur compounds can be emitted from the oil refining or sulphur-recovery processes.

2.4 Asphalt Plants

Asphalt plants combine an asphalt cement liquid (a by-product of the oil refining process) with an aggregate material. The asphalt oil is usually heated to assist in the pouring of the finished asphalt product. Volatile organic compounds and some reduced-sulphur compounds are released from the asphalt cement during the mixing of the asphalt cement with the aggregate (especially if the mixing process occurs in the presence of a flame - as in a drum asphalt plant) and during the pouring and cooling of the asphalt product. The amount of volatile organic compounds that are is released from the asphalt varies with the temperature that the asphalt cement is heated to and maintained at.

2.5 Rendering Plants

Rendering plants recycle animal and poultry by-product materials to produce both edible fats and proteins for human consumption and inedible applications. The rendering process includes a cooker and press to separate the fat from the solids. Rendering plants can also include a blood processing and drying operation.

Primary sources of odour at a rendering plant include emissions from the cooker drain pan; screw press and blood dryer. Research work has identified a few constituents of the complex mixture of odorous materials from a rendering plant and include amines, aldehydes and a variety of complex volatile organic compounds.

2.6 Foundries

Grey-iron foundries produce castings from the melting of scrap iron/steel in a cupola furnace (vertical, cylindrical shaft furnace). The molten iron is typically poured into sand molds and allowed to cool. The sand molds are bound together into the appropriate shape using chemical binders that often contain odorous amine compounds. Odorous emissions are primarily released during the pouring of the molten metal into the molds and during the separation of the mold from the cooled casting.

2.7 Landfills and Compost Facilities

The decomposition, in the absence of oxygen (i.e., anaerobic decomposition) of organic material results in the formation of a complex mixture of materials that is primarily carbon dioxide and methane (approximately 50% by volume of each compound) but also includes small amounts of odorous reduced-sulphur compounds and a variety of volatile organic compounds. Therefore, landfill gas is highly odorous. The incoming waste material may also be odorous due to the initial stages of decay and the presence of odorous volatile organic compounds (i.e., paint solvents, cleaners, etc.).

The composting of leaves, grass clippings and other plant wastes should not result in odorous emissions if the composting process is kept aerobic (i.e., with plenty of oxygen through regular turning and mixing). However, at many composting sites there are times when the incoming materials have been sitting for a period of time and allowed to decay in an anaerobic manner. This results in off-site odour impacts from the complex mixture of by-products from the anaerobic decomposition of the compost material.

2.8 Paint and Printing Operations

Painting (i.e., auto-body and/or furniture varnishing or painting operations) and printing facilities are sources of odorous volatile organic emissions. Most paints and printing inks contain a pigment material in suspension with a solvent that typically contains at least some volatile organic compounds (alkyd-based paints contain up to 50% organic solvent and water-based paints contain up to 10% organic solvents). However, low-odour/low-solvent paints are becoming more common.

2.9 Wood Dryers

Particleboard and plywood manufacturers employ the use of wood dryers to dry the raw-material wood chips prior to gluing the chips together. Wood dryers are typically fired with sawdust, natural gas or oil but the odorous emissions come from the wood chips. Wood contains natural resins to hold the wood fibres together and when they are heated, a significant amount of the volatile portion of the resins are emitted. An odorous "blue-haze" emission can result from a wood drying operation. Some portions of the "blue-haze" emission may also condense out as a sticky particulate once atmospheric conditions cool the exhaust. The amount of odorous blue-haze varies with the operating temperature of the dryer.

The gluing operation of a particleboard or plywood plant can also result in odorous emissions.

2.10 Wood Combustion in Fireplaces

Residential fireplaces are a common cause of odour complaints because of the relatively inefficient combustion (poor mixing/cool temperatures) in a fireplace and the complex volatile organic or polyaromatic compounds that result.

3. TECHNOLOGIES FOR ODOUR ABATEMENT

There are a variety of technologies available to control odorous emissions but the effectiveness of each of the technologies will depend upon the characteristics of the emission stream. For example, the concentration and type (i.e., reduced-sulphur compound versus volatile organic compound) of the odorous pollutant; and the quantity of emission to treat are important parameters in the selection of the appropriate technology.

The following provides a description of a few of the available technologies and where they have been typically applied:

3.1 Condensation

Many odorous gas streams from a process are moisture-laden and an indirect air or water-cooled heat exchanger can be used to remove both the moisture and any condensible volatile organic compounds. Condensers are often used as a first-stage of an odour control system.

3.2 Scrubbers

Scrubbers that employ chemical solutions are often used to control odorous emissions. The selection of the appropriate scrubbing solution is dependent upon the type and concentration of the odorous emission stream. However, sodium hypochlorite and chlorine dioxide are effective chemical oxidants that are commonly used to convert/oxidize an odorous stream.

A multi-stage scrubbing system is often used in process streams that contain other types of pollutants, such as particulate, in addition to odour. For example, a venturi or spray-type scrubber could be used to remove particulate up-stream of the injection of the chemical oxidant scrubbing solution. This will often can result in a more effective control of the odorous emissions when particulate emissions are present.

Scrubbers are often used to control odour from rendering plants, pulp and paper facilities and foundries.

3.3 Activated Carbon Adsorption

Physical adsorption is the term for a natural phenomenon where contaminants (adsorbates) are attracted and held to the surface of another material (adsorbent). Inter-molecular forces; the differences in concentration of the adsorbate between the solution (liquid or gaseous) and the surface pores of the adsorbent; and chemical activity between the adsorbate and adsorbent are the primary driving forces for adsorption. Activated carbon is often used as an adsorbent material for both liquid and gaseous streams of organic contaminants.

However, adsorbent filters such as activated carbon filters require replacement after the surface "sites" have been filled up by the contaminant. This is especially

important in complex mixtures where there may be a stronger affinity between the carbon and a specific contaminant in the mixture. As the carbon sites begin to fill-up some of the stronger-affinity contaminants will begin to replace or "strip" the other contaminants off. Therefore, the size and replacement frequency for the carbon filter must be selected in conjunction with a review of the contaminant stream to be controlled.

Carbon adsorption filters are very effective for odour control when the stream to be controlled is relatively consistent and predictable. Carbon adsorption filters have been effectively employed at sewage treatment plants and gasoline bulking stations for control of organic/odorous air emissions. Care must be taken when selecting the use of carbon adsorption for situations where the odorous mixture is poorly characterized or highly variable.

3.4 Thermal and Catalytic Incineration

Fume incineration is an effective technique for addressing high-concentration/low-volume odorous gas streams that contain both volatile organic compounds and reduced-sulphur compounds. Incineration can also be used for low-concentration high volume sources but the operating costs for purchased supplementary fuel can be significant.

The operating temperature and residence time (amount of time allowed at the appropriate combustion temperature) are important design parameters for a fume incinerator. A typical specification for effective combustion of non-chlorinated volatile organic compounds is 875 degrees Celsius for 0.75 second residence time.

Catalyst can be used to reduce the necessary oxidation temperature and supplementary fuel requirements of fume incineration. Selection of the specific catalyst material is dependent upon the constituents within the gas stream to be incinerated. For example, chrome/alumina, cobalt oxide and copper oxide/manganese oxide have been demonstrated to control emission streams containing chlorinated compounds while platinum-based catalysts are often employed for control of sulphur containing volatile organic compound mixtures (platinum-based catalysts are sensitive to chlorine poisoning).

Adsorption-type systems (i.e., carbon) can also be used in conjunction with incineration to assist in concentrating low concentration odorous streams.

3.5 Biofiltration

A biofilter is an engineered system that employs biologically active microorganisms in the natural process of biodegradation to break-down or convert a variety of organic compounds. Soil-bed biofilters have been used extensively in the area of wastewater treatment for decades. However, biofiltration has also begun to be used to control odorous emissions from composting facilities and industrial sources such as rendering plants.

The effectiveness of the use of microorganisms and the biodegradation process is dependent upon the specific contaminants to be controlled and maintenance of optimal conditions such as pH, temperature, moisture content and the constant flow of nutrients. In addition, the selection of the specific microorganisms may require Federal Government approval.

3.6 Odour Modification/Masking

The use of odour masking agents involves the addition of odorous substances that can change the tone/character of an odour but may increase the intensity of the odour. Both the character and intensity of an odour can be modified through the addition of compounds that result in a chemical reaction between the odorous contaminants and the added compounds.

Care should be taken in the use of odour modification and masking to ensure that the result is predictable and consistent. In addition, because of the subjective nature of odour impacts the use of odour modification/masking may result in only a short-term improvement or a solution for a portion of the affected community.

3.7 Dilution CAN be the Solution (in some cases)

Although dilution is not a primary method of odour control, poor atmospheric dispersion can be a cause of odour impacts. Therefore a review of the location and dispersion from the exhaust point should be conducted. **Is there an air in-take or openable window nearby? Does the exhaust from the stack "down-wash" to the affected area because of poor atmospheric dispersion, stack caps that inhibit vertical discharge, and/or local geometry?**

The replacement of a "hat-type" rain cap with a vertical-discharge cap can assist in alleviating poor dispersion in some situations. However, a careful review of the local community should be conducted before raising a stack or other dispersion enhancing device/approach to avoid simply transferring the odour problem to another part of the local community.

The injection of odourless dilution air into a process stream can also mitigate an odour impact.

3.8 Operation and Maintenance Aspects for Effective Odour Control

The long-term success of the use of technologies for odour abatement is dependent upon both a careful selection of the appropriate equipment and on-going operation and maintenance activities. For example, a monitoring of the temperature and any appropriate adjustment of supplementary fuel requirements of the fume incinerator is useful in ensuring its on-going effectiveness; carbon adsorption filters should be monitored for break-through of the critical contaminant (the contaminant in an emission stream that is anticipated to break-through the filter first) and replaced frequently; biofilter parameters should be monitored and any appropriate adjustments made; and the scrubber solution and hardware checked for proper operation.

An operation, maintenance and record-keeping manual should developed and up-dated based upon recommendations of both the equipment supplier and plant operating personnel.

4. COMMUNITY SURVEYS

In many cases of odour impacts, it is difficult to identify the specific source(s) of the odorous emissions. This is especially true in neighbourhoods where there are a variety of similar sources of emissions or in the vicinity of large industrial facilities. A properly designed community odour survey can be used to assist in identifying the primary source(s) of odour impacts. In addition, the on-going use of community surveys can assist in measuring the performance of any odour abatement program.

In the case of a community survey in the vicinity of an automobile manufacturing facility, five trained observers surveyed the community twice daily for a two-four week period. Current wind conditions, determined by reviewing data from a local meteorological station dictated the area for study in each period. At each of seven observation stops per observer, ten odour observations were taken at one minute intervals. Each observation included the presence, and if present, the character and intensity of the odour.

Community odour survey statistics by location, frequency, intensity and character in conjunction with facility operating records can provide the basis for development of an odour abatement plan.

5. OTHER APPROACHES TO ODOUR ABATEMENT

Although there are a variety of technologies available to mitigate odorous emissions there are a number of community and process-related techniques that are important for the on-going success of any odour abatement program.

5.1 Controlling the Process

Process monitoring and control can be used to minimize, anticipate and improve the response to situations that cause adverse odour impacts. For example, temperature monitoring and control for sources (such as wood dryers and asphalt plants) of odorous volatile organic compounds can assist in reducing these emissions. In addition, the selection of raw materials (i.e., low-sulphur coals; low-solvent coatings) that have reduced or minimal odour-causing compounds can assist in minimizing odour impacts.

In summary, incorporating an odour abatement plan with on-going process operations can not only mitigate but prevent odour impacts in the local community.

5.2 Implementing Codes of Practice

Process monitoring and control efforts within an odour abatement program can result in a code of practice for facility operators. In many situations, these codes of practice or operation manuals can be developed and implemented by the facility or appropriate trade organization.

5.3 Complaint Response and Effective Community Relations

Odour impacts typically result in complaints or concerns expressed to the Ministry and, upon validation of the impacts, a request or requirement by the Ministry for abatement by the appropriate facility. However, in an effort to improve the linkage and accountability between those impacted and the offending facility a "complaint response plan" can be initiated by the facility operators.

An effective complaint response plan is an extension of the operating procedures of the plant and may include a dedicated local telephone number; record-keeping and log-in procedures; coordination with plant operating records; follow-up procedures and record-keeping; and on-going review and approval by the plant management. To be effective, a complaint response plan should be viewed by plant personnel as an important extension of process and product monitoring information.

In many situations, diligent implementation of a complaint response plan by facility operators can result in improved communication and understanding between themselves and the local community and, over the long-term, reduced impacts on the community. Organizing a community-relations group (including members from local residential, commercial and industrial groups) may also be useful.

5.4 Land Use Planning

Although land-use planning is not a primary odour abatement tool, poor land-use planning can result in complaints of severe odour problems that even the most effective technology or technique cannot overcome. Proper land-use planning can be the most effective technique against some odour problems (i.e., landfills) because it can prevent impacts from occurring.

For more information or assistance with odour impacts, please contact the Environmental Engineering Services Section (Manager - Ed Turner, 416 323-5156).